HOW TO EVALUATE A MODEL

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THE SITUATION

LOTS & LOTS OF DATA **PRODUCTS**

COMPLEX (SOPHISTICATED) MODELS

But How Do You Analyze?

THE CHALLENGE

Multi-Variate, Non-Linear

Strong Scale Dependencies

Very Large Number of Degrees of Freedom

How is Model to be Evaluated?

Current Practices

"BLOB comparisons" of State Variables, Separately

Linear Correlations of Pairs of State Variables

Sometimes Time Variations are Examined
But Usually Interannual-to-Decadal Scales

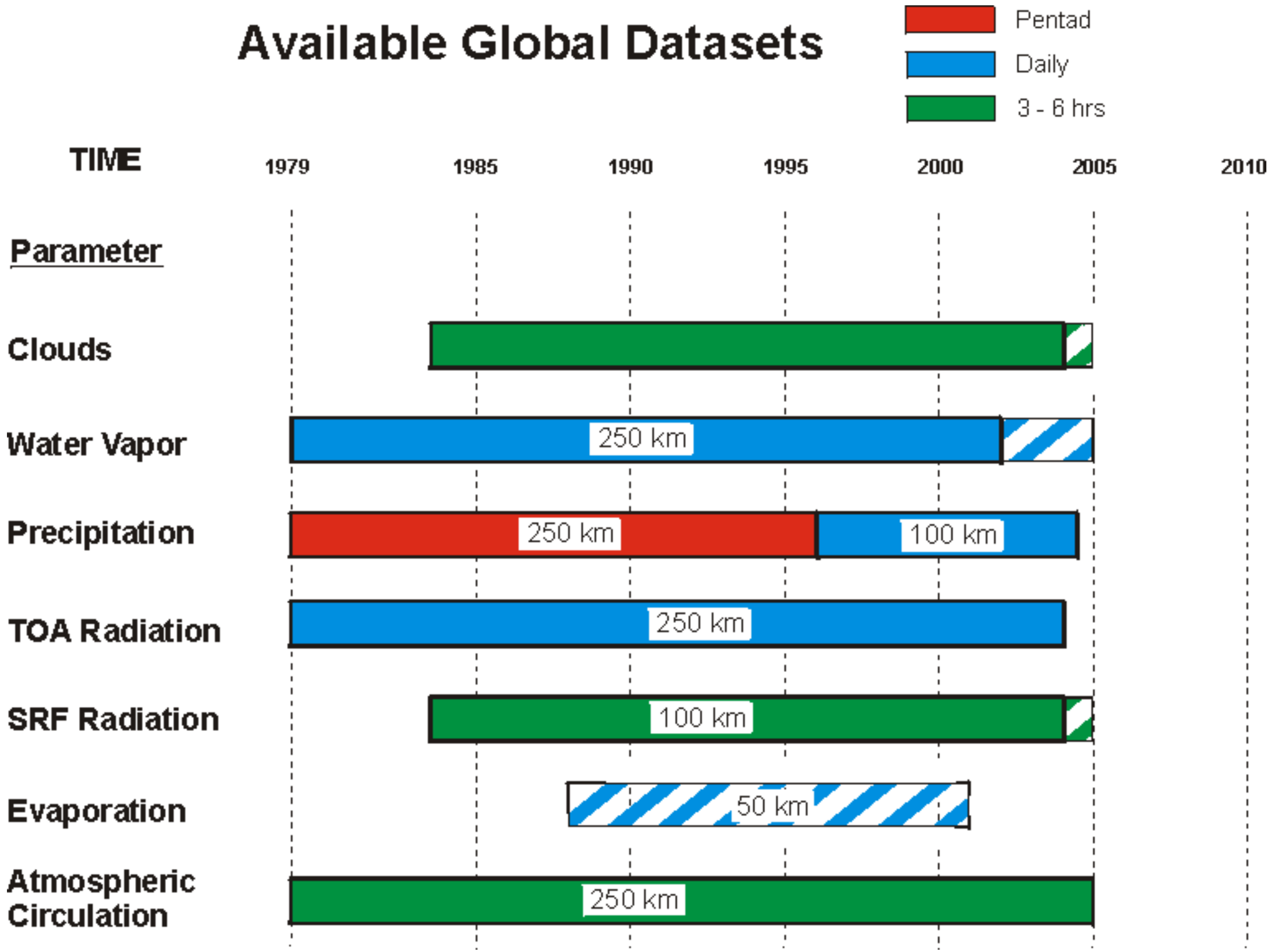
How is Model to be Tested?

Characterize Behavior (State & Variability)

Investigate Reasons for Model Behavior
In Comparison with Nature’s Reasons

Correlate Forcing and Response

Processes Revealed in Exchanges


Available Global Datasets
Pentad
Daily
3 - 6 hrs
TIME
1979
1985
1990
1995
2000
2005
2010
Parameter
Clouds
Water Vapor
250 km
Precipitation
250 km
100 km
TOA Radiation
250 km
SRF Radiation
100 km
Evaporation
50 km
Atmospheric Circulation
250 km

EXAMINE BEHAVIOR EVERY TIME SUBSTANTIAL CHANGES ARE MADE

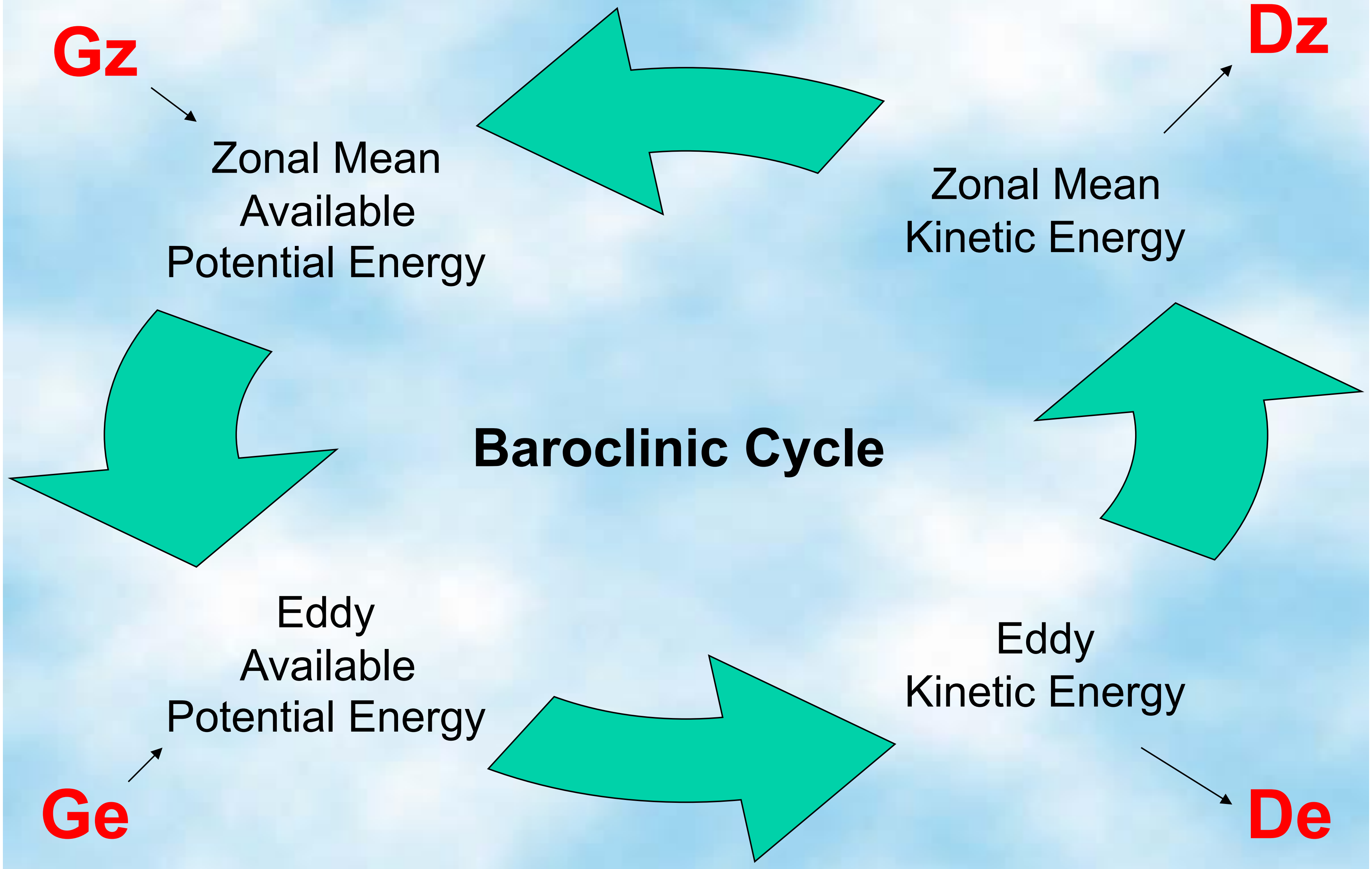
► FORCED RESPONSES:

- Mean Heating
- Diurnal Solar Heating Variations
- Seasonal (Latitudinal) Solar Heating Variations
- Volcanoes, Solar Cycle
- Shorter-Term: ENSO, AO, PDO

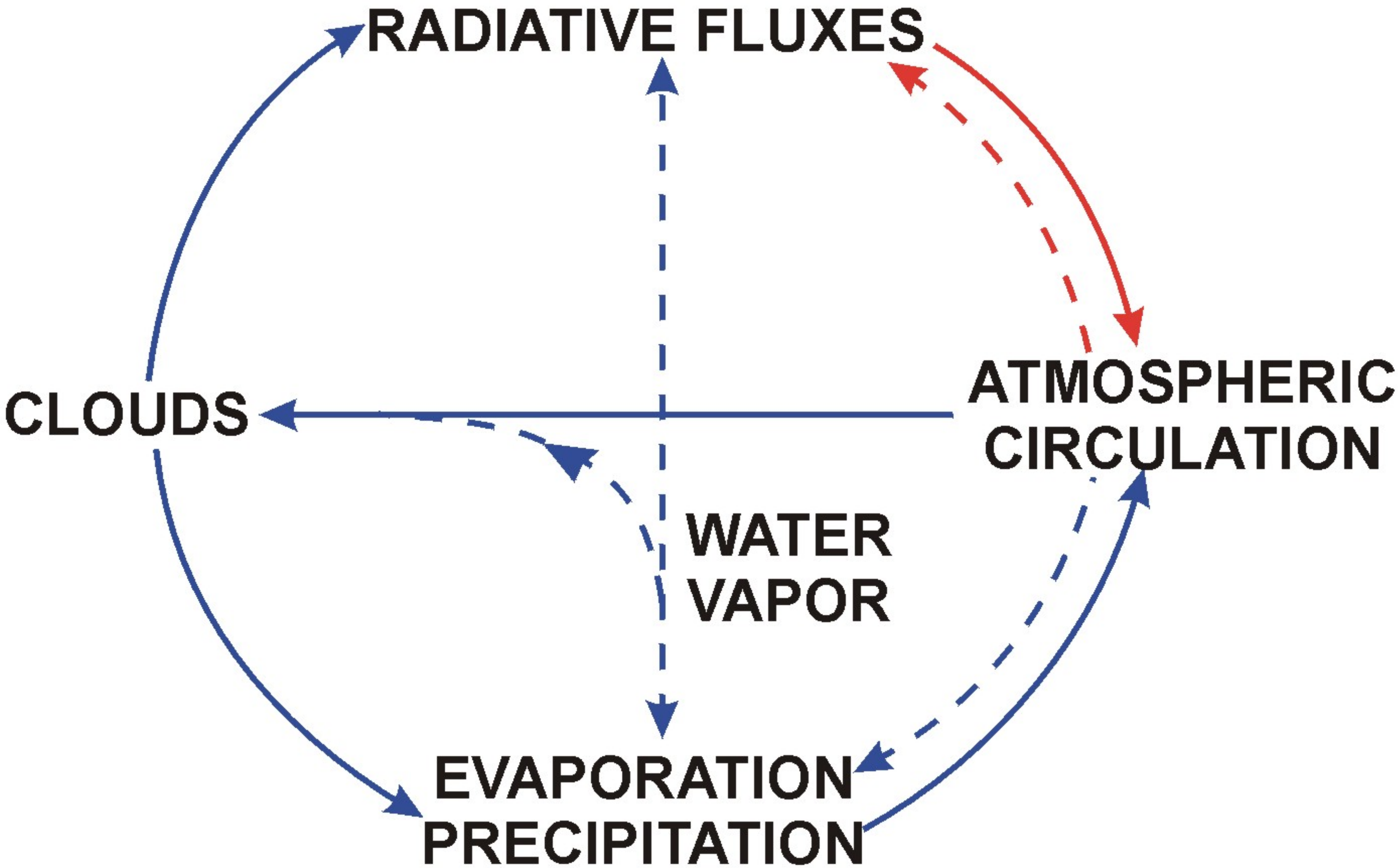
► UNFORCED VARIABILITY (Statistics):

- Convective Instability
- Baroclinic Instability
- Other Dynamic Instabilities (MJO)
- Cloud Dynamics

Energy Cycle of Atmosphere



ENERGY AND WATER CYCLE OF CLIMATE



How is Model to be Evaluated?

What Else Could be Done?

Looking at Equations

1. Divergence of Flow = Cloud-Precipitation Evolution

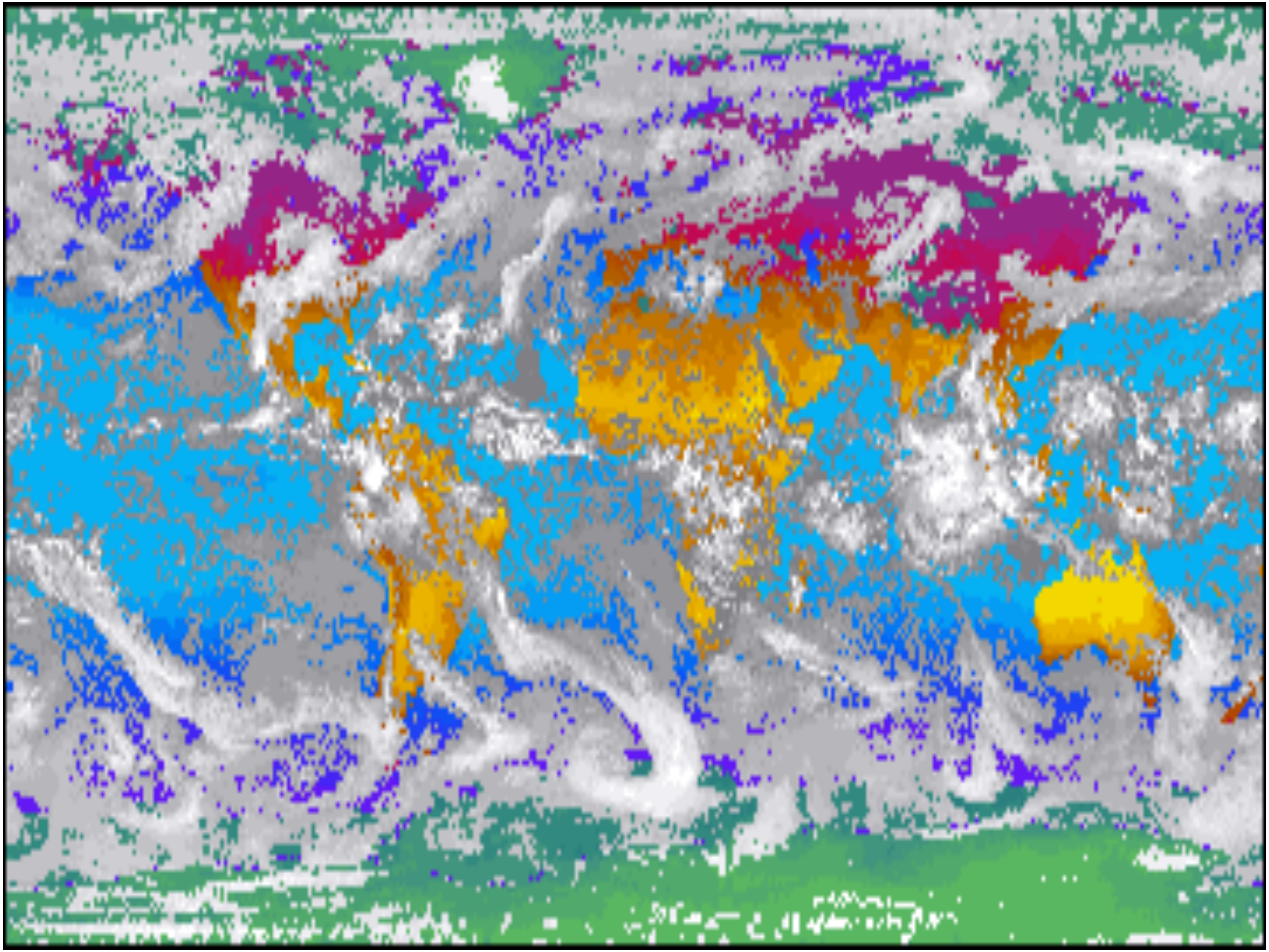
2. Meteorological Relations

3. Tendencies of Multi-Variate State (NN)

4. Rates of Exchange of Mass, Energy and Momentum

The Basic Equations

- Mass $\quad d\rho/dt = -\rho\,(\mathbf{del} \bullet \mathbf{V})$
- Energy $\quad dT/dt = (1-\gamma)T\,(\mathbf{del} \bullet \mathbf{V}) + Q/c_V$
- Momentum $\quad d\mathbf{V}/dt = -2\boldsymbol{\Omega} \text{ x } \mathbf{V} - \rho^{-1}\,\mathbf{del}\,P + g + F$
- State $\quad P = \rho RT$
- Water Cycle $\quad dq/dt = -q\,(\mathbf{del} \bullet \mathbf{V}) + Ev - Pr$



CLOUDS ARE **NOT**

AN EQUILIBRIUM STATE

USUALLY **NOT**

EVEN BALANCE OF RATES

TWO CRITICAL CLOUD CHANGES

PHASE OF CLOUD PARTICLES

SIZE OF CLOUD PARTICLES,
PRECIPITATION ONSET

NUMBER OF CLOUD PARTICLES
IS NOT TOO CRITICAL

Estimating Tendencies with Neural Network

Assume that all changes are linear for small time step

Since Observations are Incomplete,

Estimate is **Inherently Statistical**

Same Quantities can be Analyzed in Model and Obs

Lorenz Discrete Model

$$
\begin{cases}
X(t+1) = \Delta t[-Y(t)^2 - Z(t)^2 + a\,F] + (1 - a\,\Delta t)\,X(t) \\
Y(t+1) = \Delta t[-b\,X(t)\,Z(t) + G] \quad + (1 - \Delta t + \Delta t\,X(t))\,Y(t) \\
Z(t+1) = \Delta t\,b\,X(t)\,Y(t) \quad + (1 + \Delta t\,X(t) - \Delta t)\,Z(t)
\end{cases}
$$

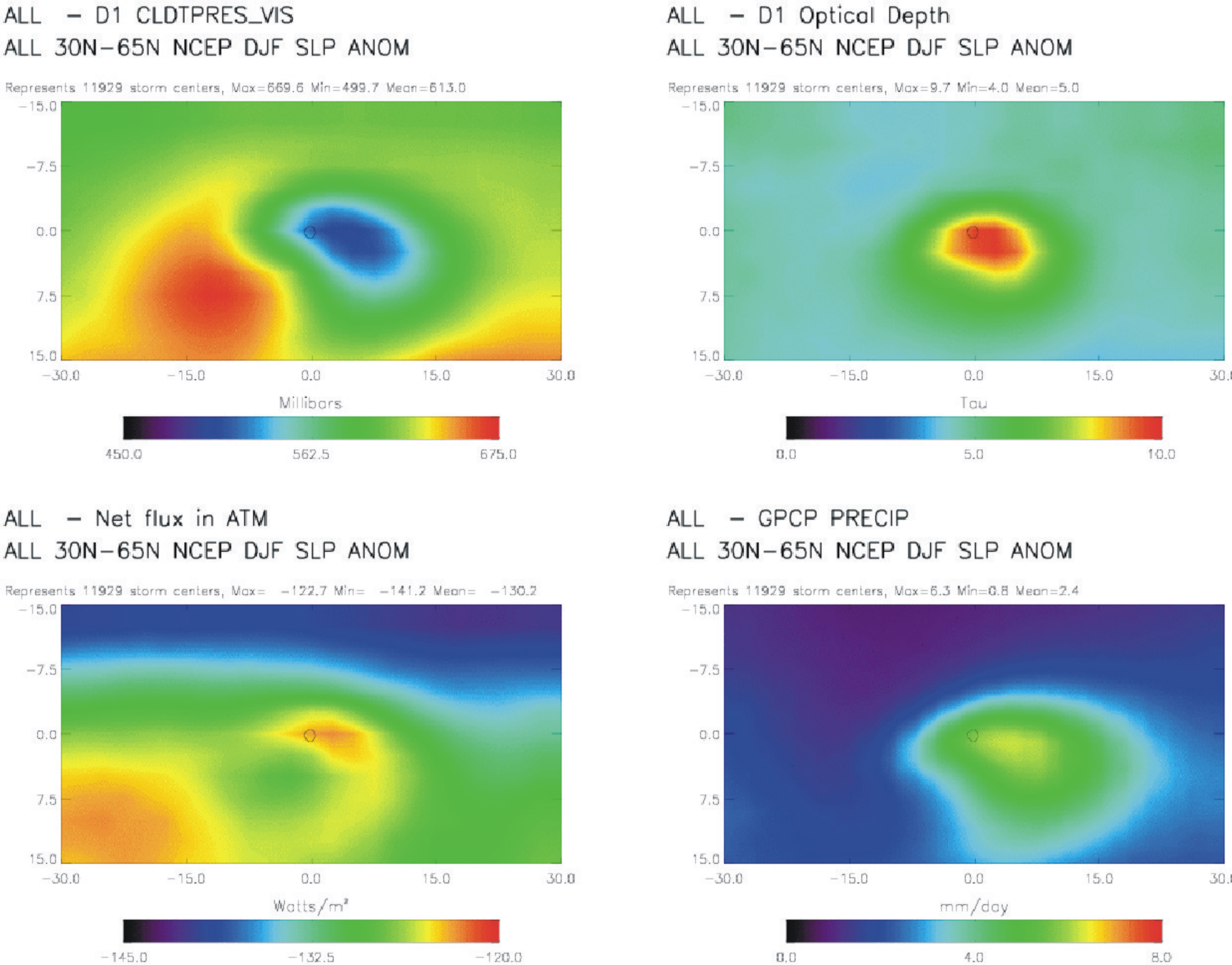
where Δt is the discrete time step.

Sensitivities of the dynamical system

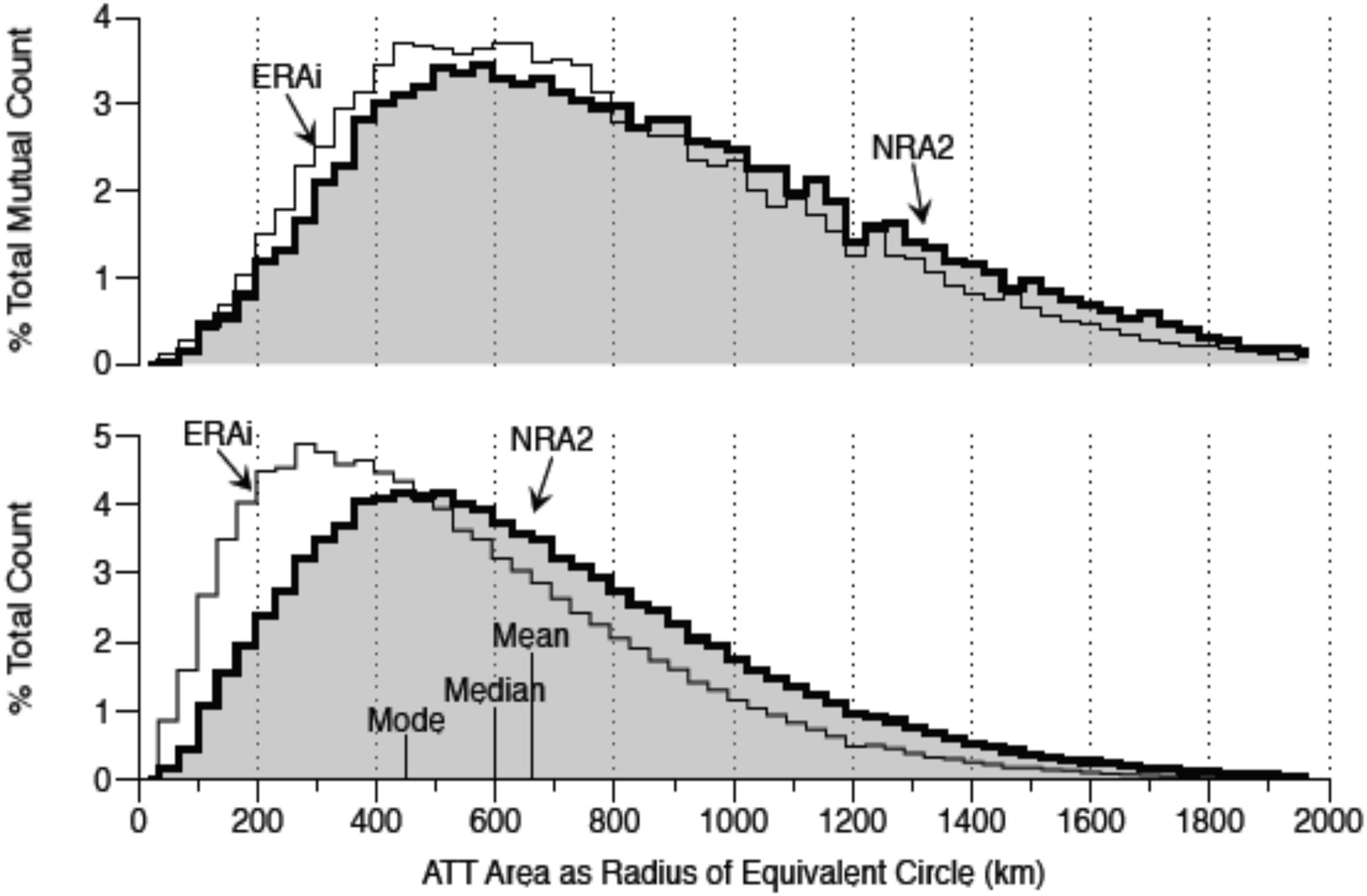
$$J\begin{pmatrix} X(t+1) \\ Y(t+1) \\ Z(t+1) \end{pmatrix} = \begin{pmatrix} \dfrac{\partial X(t+1)}{\partial X(t)} & \dfrac{\partial X(t+1)}{\partial Y(t)} & \dfrac{\partial X(t+1)}{\partial Z(t)} \\ \dfrac{\partial Y(t+1)}{\partial X(t)} & \dfrac{\partial Y(t+1)}{\partial Y(t)} & \dfrac{\partial Y(t+1)}{\partial Z(t)} \\ \dfrac{\partial Z(t+1)}{\partial X(t)} & \dfrac{\partial Z(t+1)}{\partial Y(t)} & \dfrac{\partial Z(t+1)}{\partial Z(t)} \end{pmatrix}$$

$$= \begin{pmatrix} 1 - a\Delta t & -2\,\Delta t\, Y(t) & -2\,\Delta t\, Z(t) \\ -\Delta t\, b\, Z(t) + \Delta t\, Y(t) & 1 - \Delta t + \Delta t\, X(t) & -b\,\Delta t\, X(t) \\ \Delta t\, b\, Y(t) + \Delta t\, Z(t) & \Delta t\, b\, X(t) & 1 + \Delta t\, X(t) - \Delta t \end{pmatrix}$$

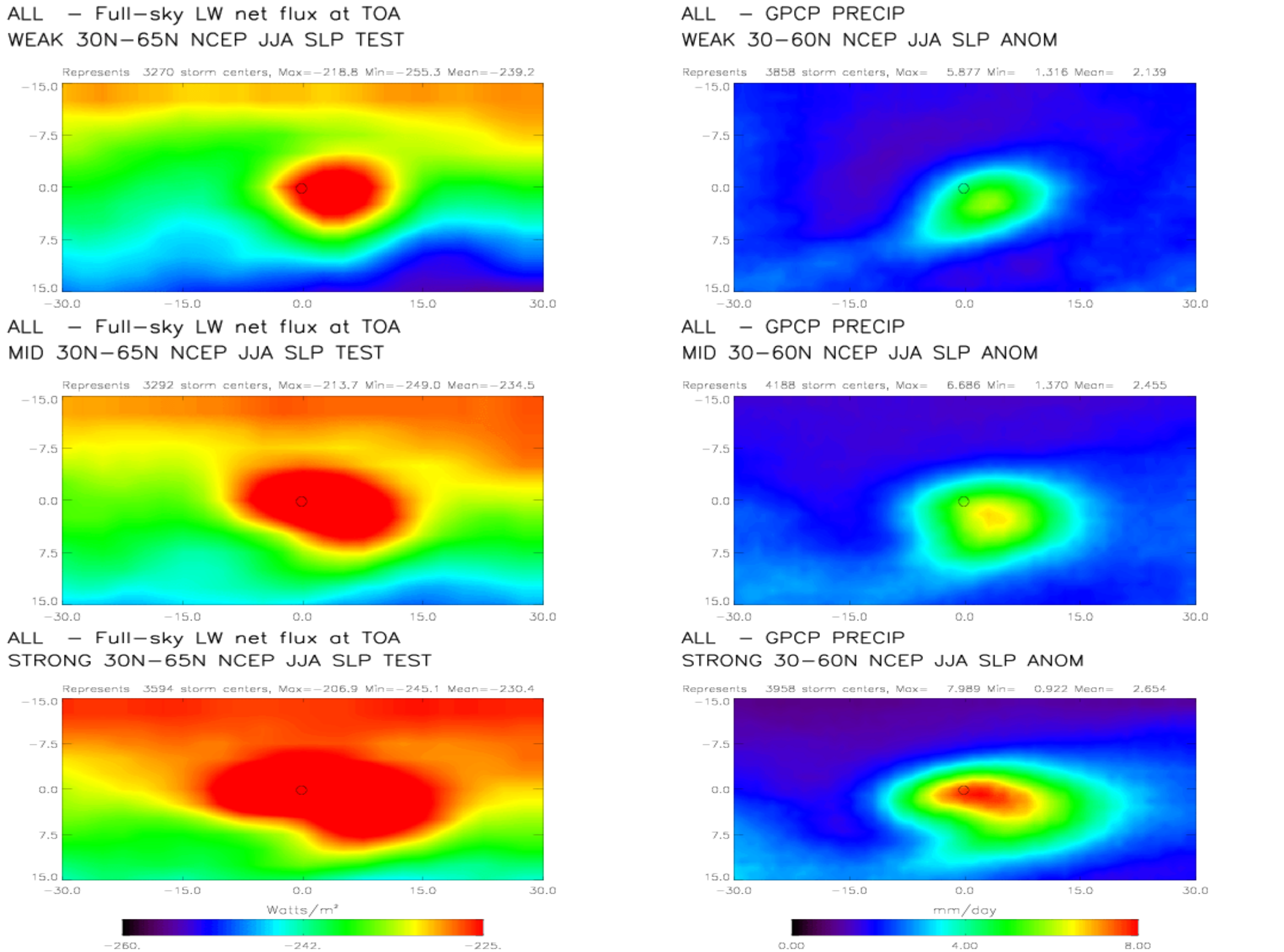
Conditional Sorting by Meteorological Events


ALL – D1 CLDTPRES_VIS
ALL 30N–65N NCEP DJF SLP ANOM
Represents 11929 storm centers, Max=669.6 Min=499.7 Mean=613.0
Millibars
450.0
562.5
675.0
ALL – D1 Optical Depth
ALL 30N–65N NCEP DJF SLP ANOM
Represents 11929 storm centers, Max=9.7 Min=4.0 Mean=5.0
Tau
0.0
5.0
10.0
ALL – Net flux in ATM
ALL 30N–65N NCEP DJF SLP ANOM
Represents 11929 storm centers, Max= –122.7 Min= –141.2 Mean= –130.2
Watts/m²
–145.0
–132.5
–120.0
ALL – GPCP PRECIP
ALL 30N–65N NCEP DJF SLP ANOM
Represents 11929 storm centers, Max=6.3 Min=0.8 Mean=2.4
mm/day
0.0
4.0
8.0
–15.0
–7.5
0.0
7.5
15.0
–30.0
–15.0
0.0
15.0
30.0

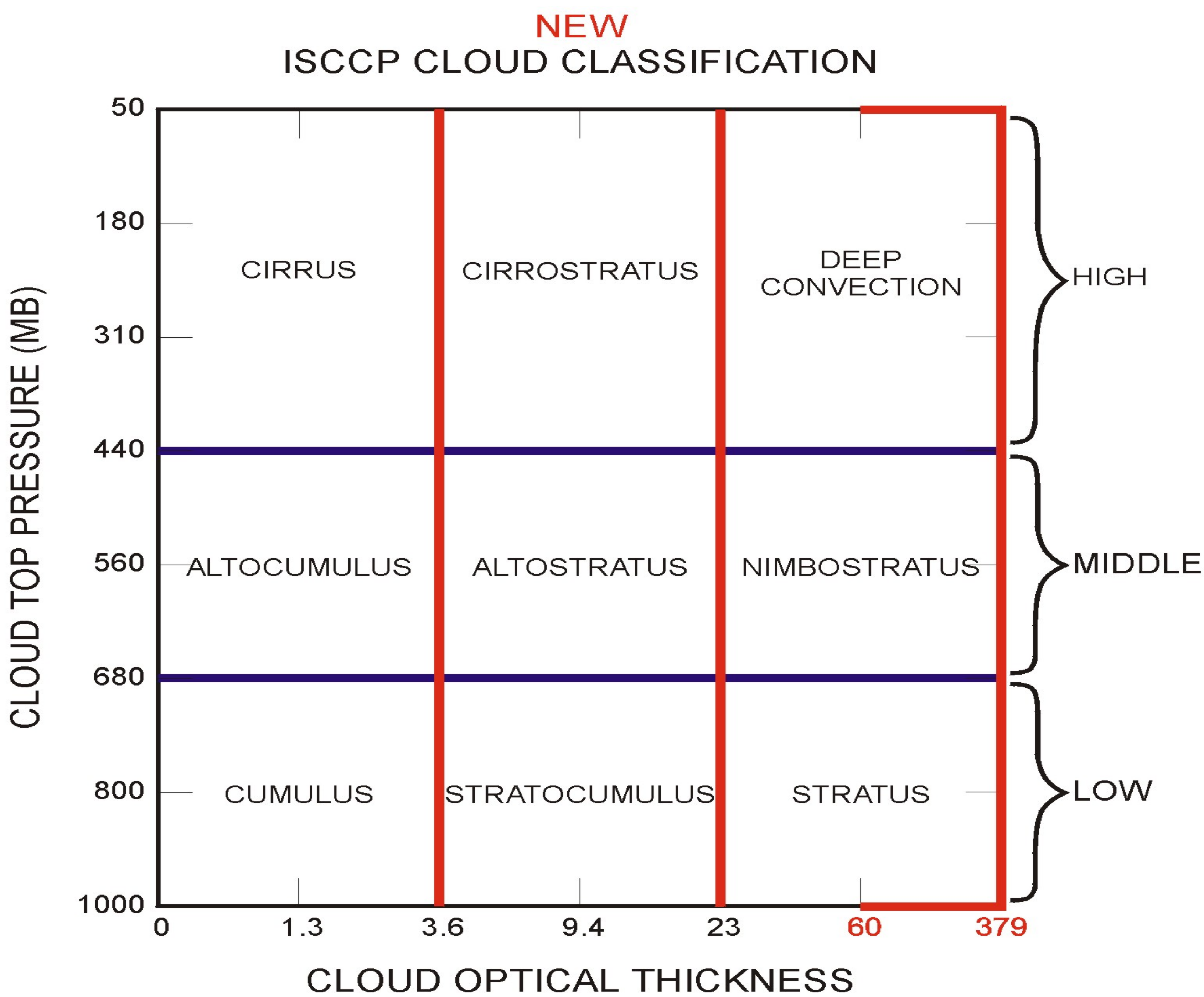
Distribution of Midlatitude Storm Sizes -- Strengths

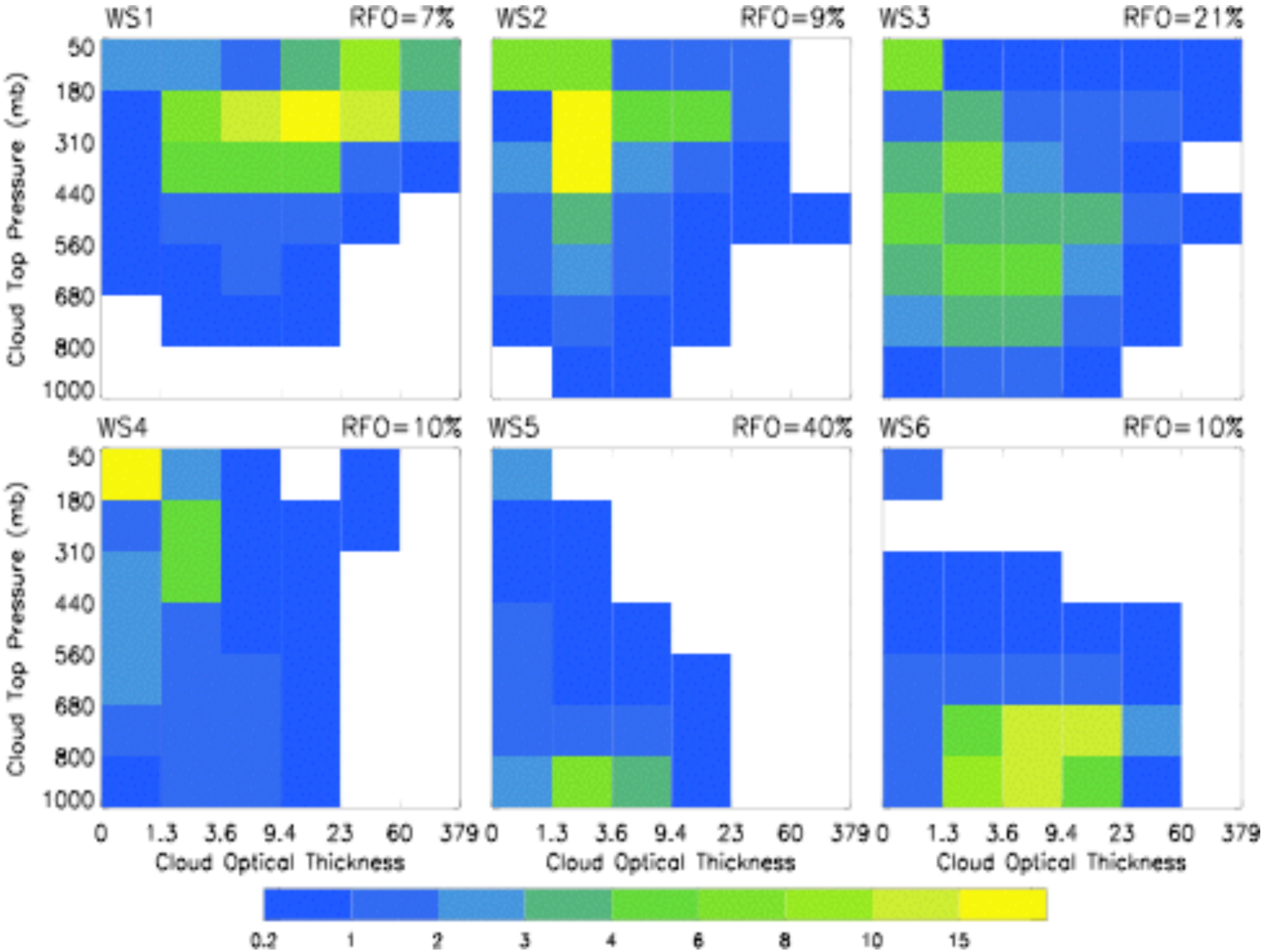


Composite of Diabatic Heating of Atmosphere with Cyclone Strength

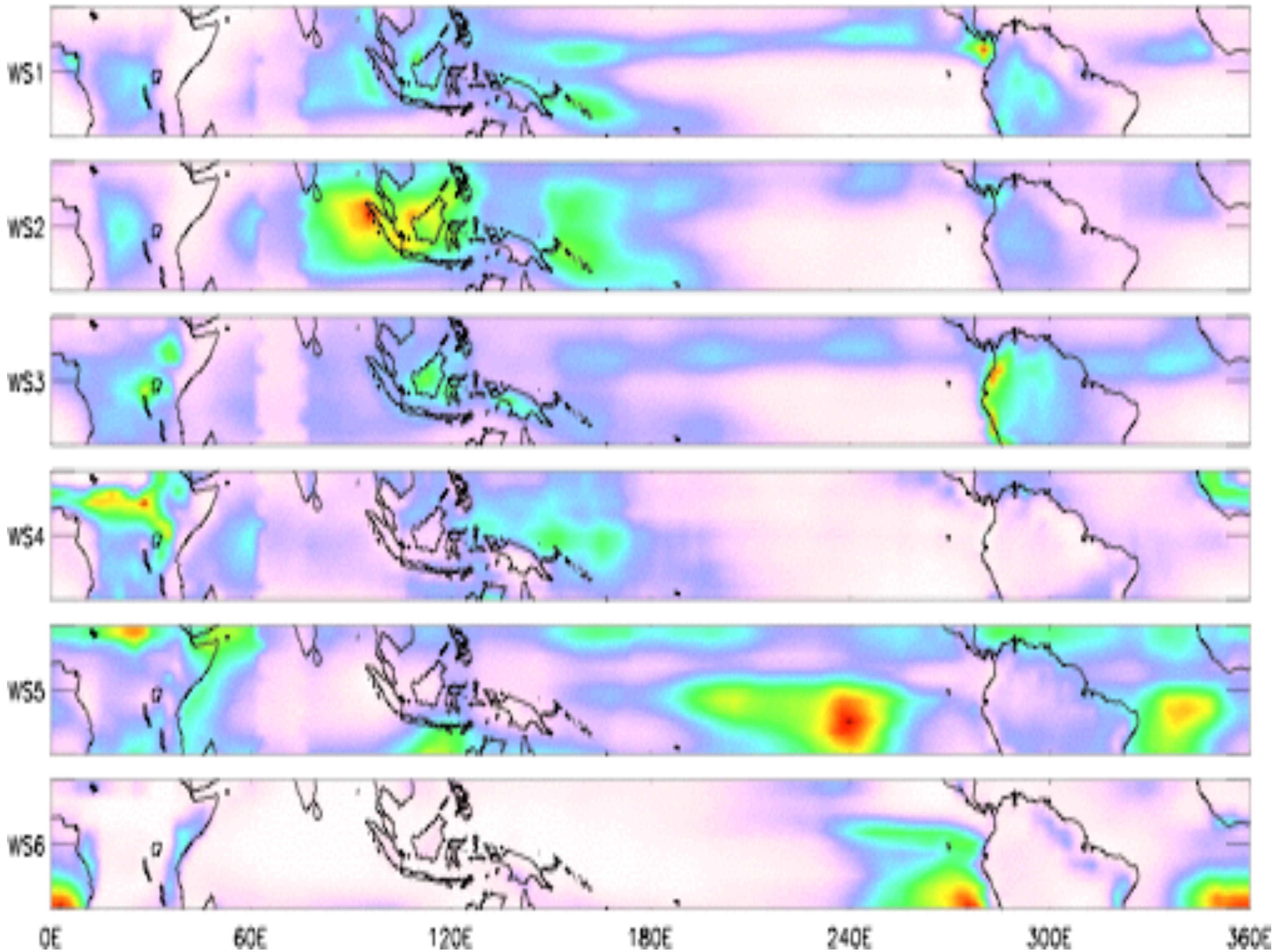


Defining Weather States

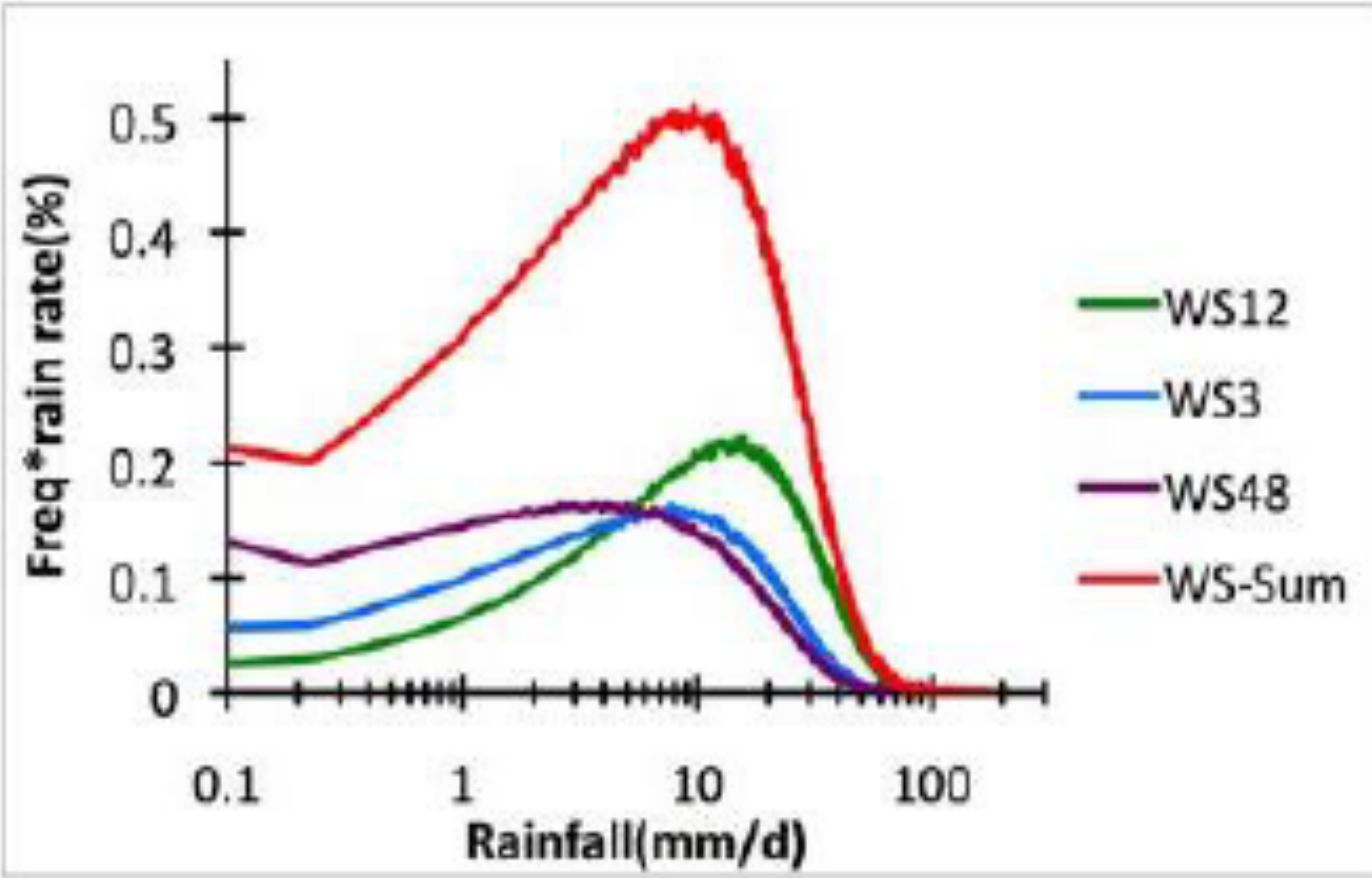

NEW
ISCCP CLOUD CLASSIFICATION
CLOUD TOP PRESSURE (MB)
50
180
310
440
560
680
800
1000
CIRRUS
CIRROSTRATUS
DEEP CONVECTION
ALTOCUMULUS
ALTOSTRATUS
NIMBOSTRATUS
CUMULUS
STRATOCUMULUS
STRATUS
HIGH
MIDDLE
LOW
0
1.3
3.6
9.4
23
60
379
CLOUD OPTICAL THICKNESS



WS1
RFO=7%
WS2
RFO=9%
WS3
RFO=21%
WS4
RFO=10%
WS5
RFO=40%
WS6
RFO=10%
Cloud Top Pressure (mb)
50
180
310
440
560
680
800
1000
0
1.3
3.6
9.4
23
60
379
Cloud Optical Thickness
0.2
1
2
3
4
6
8
10
15


WS1
WS2
WS3
WS4
WS5
WS6
0E
60E
120E
180E
240E
300E
360E

Tropical Precipitation Distribution by Weather State



When is Model Good Enough?

Weather Forecast Model Situation

Observations Available to Verify Forecast State

(But Not Very Detailed)

(And Tendencies not Verified)

Can Test Sensitivity to Observation Accuracy

(But Usually Blame Observations not Model)

Can Test Sensitivity to Model Parameterizations

And Verify (Conclusions Limited by Model)

When is Model Good Enough?

Climate Forecast Model Situation

Observations **Not** Available
to Verify Forecast State

Can Test Sensitivity to Observation Accuracy
(But Usually Blame Observations not Model)

Can Test Sensitivity to Model Parameterizations
Cannot Verify (Conclusions Limited by Model)